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The multichannel control system of LEDs with temperature stabilization

Abstract. *The publication describes multi-band control system medium power LEDs. This system supports narrowband IR and VIS LEDs. Each of these LEDs has its own driver. The control system was supplemented with temperature stabilization unit. The individual components of the system are controlled in parallel by the FPGA. Such a solution is described LED illuminator this gives you the flexibility to shape the emission spectral characteristics.*

Streszczenie*. W publikacji opisano wielokanałowy system sterujący zespołem LED-ów średniej mocy. Każda z obsługiwanych, wąskopasmowych diod IR lub VIS, posiada własny sterownik. Dodatkowy podsystem, oparty na ogniwach Peltiera, zapewnia stabilizację temperaturową całego systemu. Wszystkie podzespoły systemu sterowane są równolegle przez układ FPGA. Takie rozwiązanie można zastosować do kształtowania charakterystyki emisyjnej źródła LED-owego. (**Stabilizowany temperaturowo, wielokanałowy system sterujący zestawem LED-ów**).*

Keywords: constant current LED driver, temperature stabilization, Peltier module, FPGA.
Słowa kluczowe: stałoprądowy sterownik LED-ów, stabilizacja temperaturowa, moduł Peltiera, układ FPGA.

Introduction

There are many LEDs applications, such as lighting [1], medical [2], etc. LEDs usually do not work individually but in a multichannel system. The paper presents the new concept of such a system. It contains the following subsystems (Fig.1): a set of 25 LED drivers, 5 Peltier drivers, FTDI usb to parallel port converter, PC and control unit based on FPGA chip.

A characteristic feature of the presented solution is the large number of signal connections between the control unit and other components of the system. This forces the need for a control unit having a significant number of pins I/O. In addition, the system should be able to parallel processing of a large number of signals. These requirements are met by the FPGA array. It gives the opportunity of parallel implementation of control algorithms. Depending on complexity of the matrix, the number of terminals I/O can be up to several thousand.

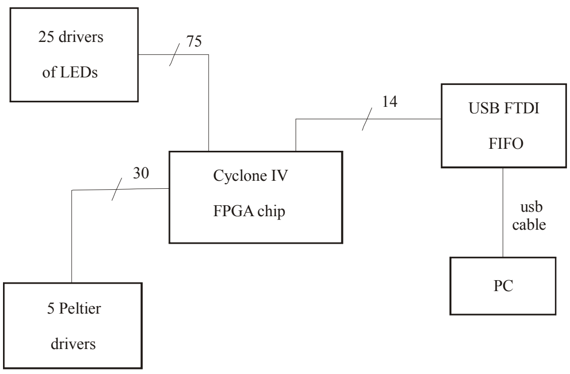

Fig.1. Block diagram of the control system

Modern control system should work with peripheral devices such as a PC. In this case, the possibility for such communication is designed using a standard USB bus. Therefore, it was necessary to apply to the signal converter USB to FPGA. Here, we use a typical converter [4] USB to 8-bit parallel port. It uses the FIFO memory depth of 256 words. That converter communicates with FPGA chip with a 14-bit bus.

The developed application is able to support up to 25 independent LED drivers. Each driver communicates with the FPGA using a 3-wire SPI bus. The signals of the bus set current intensity of the expected value of power LEDs. The proposed solution is predisposed for use in DC power system, although it is also possible power pulsed LEDs.

The LED driver scheme

The LED driver [3] circuit (Fig.2) contains three basic functional blocks: a digital potentiometer U1, a non-inverting amplifier U2 and the current amplifier [5] U3. Potentiometer output circuit is powered by a voltage reference source D1. Divided voltage from the source is amplified by U2 block. The output signal of the U2 amplifier directly controls the current amplifier by resistor R5. The U3 block amplifies 100 times the input current. The amplified output current directly feeds the diode LED1. The input current of U3 depends on value of resistance R5, and the amplitude of the output voltage U2. An additional transistor, which is connected in series with the LED, can be used to switch the bias current.

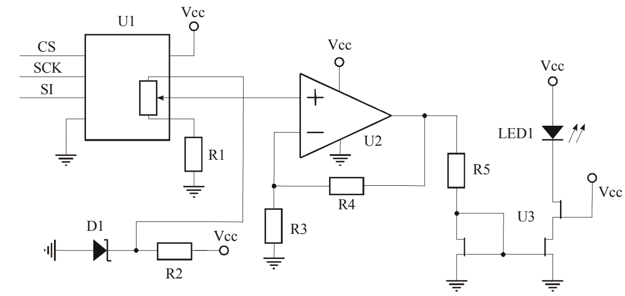

Fig.2. Scheme of the LED driver

LED current control accuracy depends on the stability of the references voltage and the resolution of the digital potentiometer. Driver frequency bandwidth limitation is a transmission speed SPI bus. In the typical cases, the upper cut-off is approximately 1 MHz. The controller can power both the individual LED and their serial connections. Limit value is the forward voltage LEDs branches, which should not exceed 33V. The discussed system can get DC power supply current up to 1A. It is inadvisable to use higher voltages than is apparent from the requirements of the driver. Any excess of the supply voltage will increase the operating temperature of the current amplifier. Exceeding the allowable power dissipation [5] requires the use of additional heat sink.

The application consists several drivers. Each driver controls the medium-power LED. A large number of LEDs produces a lot of heat. It causes the need for forced cooling system LEDs. Due to the spatial arrangement of construction, cooling system should be distributed. Heat dissipation of the system can be controlled using Peltier modules. Individual modules can be attached to the heat sink of LEDs. By adjusting the current supply Peltier module, you can control the heat dissipation efficiency of LEDs. If the cooling of LEDs is too small, you have to force a faster flow of air around the heat sinks. Next describes how to make a single Peltier module supply.

The concept of thermal stabilization subsystem

Part of the subsystem implementing the thermal stability (Fig.3) consists of two functional paths. The first one measures the LED heat sink temperature. It contains a digital thermometer U11 three optocouplers. These optocouplers are included in IC U9 and U10. Communication with the control FPGA is through I^2C bus. The thermometer for this purpose uses signals SDA_OUT, SCLK_OUT and SDA_IN. The second track is a Peltier module supply circuit. In this track FPGA communicates with U12 potentiometer in one direction via SPI bus. Control signals (CS_Pelt, SCK_Pelt, SO_Pelt) are supplied by optocouplers in U10 chip. Digital potentiometer output was turned in the adjustable voltage regulator U13. By changing the setting of the potentiometer can be changed Peltier module supply voltage Vp. The Peltier module voltage is higher the higher is the efficiency of heat dissipation.

The FPGA chip manages the thermal stabilization subsystem. Temperature control is carried out in the feedback circuit. Control algorithm inputs are the measured temperature of a hest sink and the temperature assumed by the user. If the input signals are different error signal is formed. This signal changes the digital potentiometer settings. Potentiometer setting changes increase or decrease the current Peltier module.

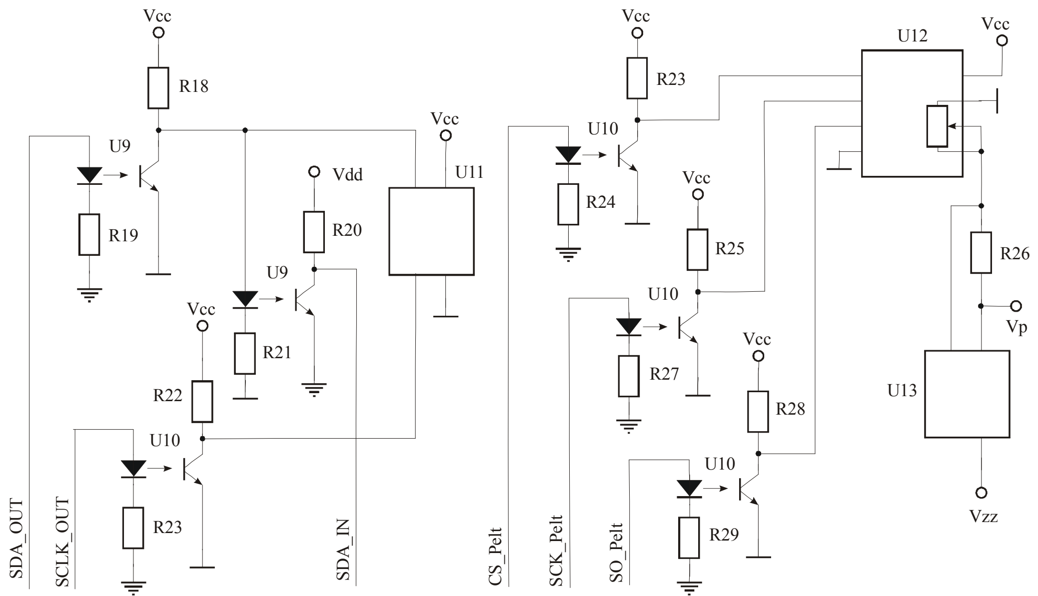

Fig.3. Scheme of thermal stabilization subsystem

Digital control unit

The digital control unit of the system has been implemented based on FPGA Cyclone IV family. Design of digital control system is made using the Quartus II Web Edition software. Control algorithms are programmed in VHDL. The FPGA communicates with the environment through the ports (Fig.4). The control unit can be operated either by USB bus (port FTDI[13..0]) or by using an external keyboard (port SW[17..0]). Clock signal is entered to the system by Clock port. LED drivers control signals were derived by the output LEDs[2..0][24..0] port. Communication with temperature stabilization system followed by bi-directional Peltiers[5..0][4..0] port.

The control unit shown in Figure 4 is constructed hierarchically. It consists of sub-components as shown in Figure 5. The component Master supervises the work of executing of the main control algorithm. An external control signals through the decoder Monitor determines the performance of the whole system. The decoder converts the signals from USB port or the keyboard to 8-bit words. They contain information about the job performance LED drivers and hest sink required temperature. The Master transmits settings LED_modules by 200-bit bus. The bus signals are grouped into 8-bit words of supports the individual drivers. The LED_modules component sends control bits (CS, SCK and SI, Fig.2) in the form 25 3-bit buses. These signals are led from the FPGA through the LEDs[2..0][24..0] port.

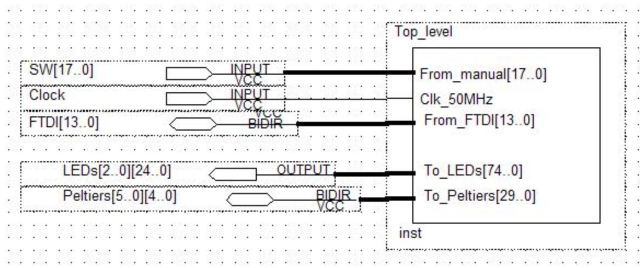

Fig.4. Top level file of control unit

Thermal stabilization modules are supported by the component Peltier_modules. This component connects to the Master via 20-bit bus. The thermal stabilization subsystems communicate with the Peltier_modules via bi-directional bus

Peltiers[5..0][4..0]. This port signals are grouped in 6-bit bus. Three younger bits (Peltier[2..0]) of the bus support digital thermometer U11 and three older (Peltier[5..3]) digital potentiometer U12. Each of the components shown in Figure 5 is also hierarchically structured. For, example the internal architecture one of the component Peltier_modules is shown in Figure 6.

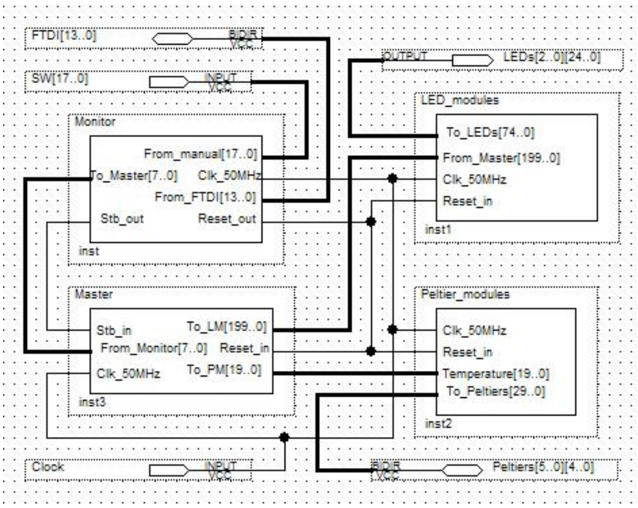

Fig.5. The functional structure of a control unit

This modules contains the following components: decoder set Temperature_decoder temperature, the thermometer Thermometer_support handler, a runtime service State_machine and potentiometer Potentiometer block. The decoder converts the temperature settings of the Master module to the format supported by the executive module. The component Thermometer_support supports digital thermometer U11 (Fig.3). It sends and receives data from the thermometer through the I^{2}C bus. This module decodes the heat sink temperature and converts it into a format the executive module. The State_machine compares data from the Temperature_decoder and the Thermometer_support. Depending on their relationship to correct the data To_Potent[7..0] component control of potentiometer. The Potentiometer component converts the data into a bus SPI format. The signals of the bus support U12 chip of Figure 3.

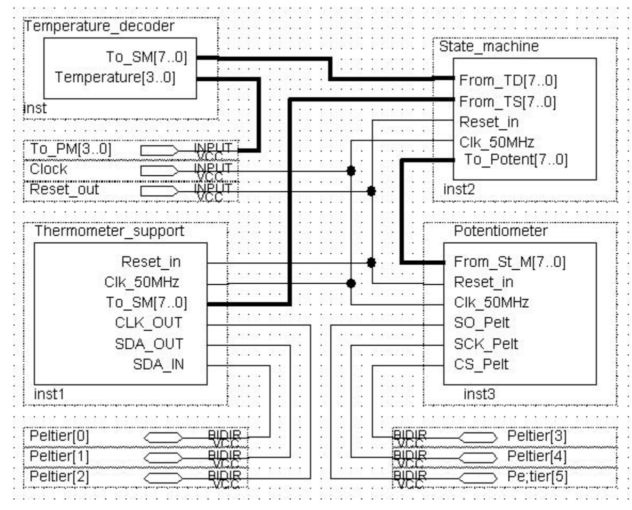

Fig.6. Thermal stabilization controller component

Summary

In multichannel system such as LED lamps need to control the number of concurrent components. At the same time, you should read, process, and issue of multiple signals. At the same time there is support for multiple process control. This can be done only in digital control systems. Therefore, measuring and executing elements of such a system have to accept this type of signals [6,7,8]. Because of the large number of external pins is required for multi-output characteristics of the driver on-chip.

This technique is used in the example multiply-controlled LEDs. The whole system is divided into the processes and components that support them. The master control process separated basic processes such as external communications support, driver radiation source support and thermal stability. The implementing components are equipped with standard elements supported by the hardware buses type SPI and I^{2}C. As the target execution digital system uses FPGA.

The resulting solution can be in a fairly wide range expanded, adding more processes and components. In this case, approximately uses 120 digital control signals from about 1,500 potentially possible. The project uses less than 10% of internal resources mid-sized FPGA. Thus, based on the resources of the digital system and the control characteristics can be achieved concurrent complex lighting system with a controlled environment. This is due to the possibility of shaping the spatial and spectral characteristics of a light source with sources in the form of miniature LEDs [9,10]. The combination of the above characteristics of the performance of modern programmable devices presents new opportunities for application in the field.

Acknowledgments
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